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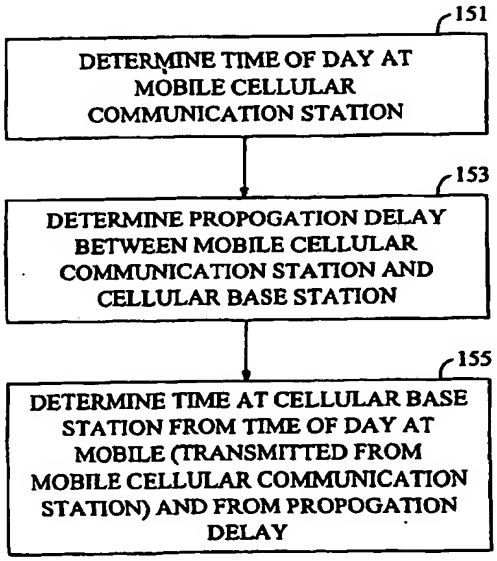

(57) Abstract: Methods and apparatuses for synchronozing basestations in a cellular network. One exemplary method performs time synchronization between at least tow basestations, a first basestation and a second basestation, of a cellular communication system. In this exemplary method, a first time-of-day and a first geographical location of a first mobile cellular receiver station (MS) are determined from a first satellite positioning system (SPS) receiver which is co-located with the first MS, and the first time-of-day and first location are transmitted by the first MS to a first basestation which determines a time-of-day of the first basestation from the first time-of-day and first location and from a known location of the first basestation. Also in this exemplary method, a second time-of-day and a second geographical location of a second MS are determined from a second SPS receiver which is co-located with the second MS, and the second time-of-day and the second location are transmitted to a second basestation which determines a time-of-day of the second basestation from the second-time-of-day and the second location and a known location of the second basestation. Other methods and apparatuses are also described for synchronizing basestations in a cellular network.

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METHODS AND APPARATUSES FOR USING MOBILE GPS STATIONS TO SYNCHRONIZE BASESTATIONS

BACKGROUND OF THE INVENTION

The present invention relates to the field of cellular communication systems, and particularly those systems where the location of a mobile cellular communication station (MS) is determined.

In order to perform position location in cellular networks (e.g. a cellular telephone network) several approaches have been utilized which perform triangulation based upon the use of timing information sent between each of several basestations and a mobile device, such as a cellular telephone. In one approach, called Time Difference of Arrival (TDOA), the times of reception of a signal from a mobile is measured at several basestations, and these times are transmitted to a location determination entity, called a location server, which computes the position of the mobile. For this approach to work, the times-of-day at the various basestations need to be coordinated to provide accurate location. Also, the position of the basestations needs to be known accurately. **Figure 1** shows an example of a TDOA system where the times of reception (TR1, TR2 and TR3) of the same signal from the mobile cellular telephone 22 are measured at cellular basestations 12, 14 and 16 by a location server 24. The location server 24 is coupled to receive data from the basestations through the mobile switching center 18. The mobile switching center 18 provides signals (e.g. voice communications) to and from the land-line Public Switched Telephone System (PSTS) so that signals may be conveyed to and from the mobile

telephone to other telephones (e.g. land-line phones on the PSTS or other mobile telephones).

In some cases the location server may also communicate with the mobile switching center via a cellular link. The location server may also monitor emissions from several of the basestations in an effort to determine the relative timing of these emissions.

An alternative method, called EOTD, measures *at the mobile* the times of arrival of signals transmitted from each of several basestations. **Figure 1** applies to this case if the arrows of TR1, TR2 and TR3 are reversed. This timing data may then be used to compute the position of the mobile. Such computation may be done at the mobile itself or at a location server, if the timing information so obtained by the mobile is transmitted to this server via the link. Again, the basestation times-of-day must be coordinated and their location accurately assessed. In either approach, the locations of the basestations are determined by standard surveying methods and may be stored in the basestation or at the server in some type of computer memory.

Yet a third method of doing position location utilizes in the mobile a receiver for the Global Position Satellite System (GPS) or other satellite positioning system (SPS). Such a method may be completely autonomous or may utilize the cellular network to provide assistance data or share in the position calculation. Examples of such a method are described in U.S. Patents No. 5,841,396; No. 5,945,944; and No. 5,812,087. As a shorthand, we call these various methods "SPS."

A combination of either the EOTD and TDOA and an SPS system is called a "hybrid" system.

It should be clear from the above description, that for EOTD or TDOA, time coordination between the various cellular basestations is necessary for accurate position calculation of the mobile. The required time-of-day accuracy at the basestations depends upon details of the positioning method utilized. In one method the round trip delay (RTD) is found for signals that are sent from the basestation to the mobile and then are returned. In a similar, but alternative, method the round trip delay is found for signals that are sent from the mobile to the basestation and then returned. Each of these round trip times are divided by two to determine an estimate of the one-way time delay. Knowledge of the location of the basestation, plus a one-way delay constrains the location of the mobile to a circle on the earth. Another measurement with a second basestation then results in the intersection of two circles, which in turn constrains the location to two points on earth. A third such measurement resolves the ambiguity. With round trip timing it is important that the measurements with the several basestations be coordinated to several seconds, at worst, so that if the mobile is moving rapidly, the measurements will correspond to those occurring at the same location.

In other situations, it is not possible to perform round trip measurements to each of two or three basestations, but only to one basestation which is the primary one communicating with the mobile. This is the case for the IS-95 North American CDMA cellular standard. Or, it may not be possible to perform accurate round trip timing measurements at all due to equipment or signaling protocol limitations. In this case, it is even more important that accurate timing be maintained at the basestations, if

a triangulation operation is to be performed, since only the time difference between mobile-basestation paths is what is utilized.

Another reason to have accurate timing present at basestations is to provide time to the mobiles for aiding GPS based position calculations; such information may result in reduced time to first fix, and/or improved sensitivity. The required accuracy for these situations can range from a few microseconds to around 10 milliseconds depending upon the performance improvement desired. In a hybrid system, the basestation timing serves the dual purpose of improving the TOA or TDOA operation as well as the GPS operation.

The prior art approaches to network timing employed special fixed location timing systems, termed Location Measurement Units (LMU) or Timing Measurement Units (TMU). The units typically included a GPS receiver which enable determination of accurate time-of-day. The location of the units may be surveyed, such as may be done with GPS based surveying equipment.

Typically, LMU's or TMU's observe the timing signals, such as framing markers, present within the cellular communication signals that are transmitted from the basestations and attempt to time-tag these timing signals with the local time found via a GPS set or other time determination device. Messages may then be sent to the basestations (or other infrastructure components), which allow these entities to keep track of elapsed time. Then, upon command, or periodically, special messages may be sent over the cellular network to mobiles served by the network indicating the time-of-day associated with the framing structure of the signal. This is particularly easy for a system such as GSM in which the total framing structure lasts over a period

exceeding 3 hours. It is noted that the location measurement units may serve other purposes, such as acting as the location servers—that is, the LMU's may actually perform the time-of-arrival measurements from the mobiles in order to determine the positions of the mobiles.

One problem with the LMU or TMU approach is that they require the construction of new special fixed equipment at each basestation or at other sites within communication range of several basestations. This can lead to very high costs for installation and maintenance.

SUMMARY OF THE INVENTION

The present invention provides various methods and apparatuses for synchronizing cellular basestations in a cellular network. One exemplary method performs time synchronization between at least two basestations, a first basestation and a second basestation, of a cellular communication system. In this exemplary method, a first time-of-day and a first location of a first mobile cellular station (MS) are determined from a first satellite positioning system (SPS) receiver which is co-located with the first mobile station (MS), and the first time-of-day and first location are transmitted by the first MS to a first basestation which determines a time-of-day of the first basestation from the first time-of-day and first location and from a known location of the first basestation. Also in this exemplary method, a second time-of-day and a second location of a second MS are determined from a second SPS receiver which is co-located with the second MS, and the second time-of-day and the second location are transmitted to a second basestation which determines a time-of-day of the second basestation from the second time-of-day and the second location and a known location of the second basestation. Since these mobile stations may be used for normal communication operations and are not necessarily fixed to a building or structure, their use for timing a network avoids the high cost of real estate to maintain fixed timing equipment. Other methods and apparatuses are also described for synchronizing basestations in a cellular network.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings in which the same references indicate similar elements.

Figure 1 shows an example of a prior art cellular network which determines the position of a mobile cellular device.

Figure 2 shows an example of a mobile cellular communication station which may be used with the present invention and which includes a GPS receiver and a cellular communication transceiver.

Figure 3 shows an example of a cellular basestation which may be used in various embodiments of the present invention.

Figure 4 is a flowchart which shows one embodiment of a method according to the present invention.

Figure 5A and **5B** are flowcharts which show another embodiment of a method according to the present invention.

Figure 6A shows two signals which are processed according to one exemplary method of the present invention.

Figure 6B shows a representation of a signal at a basestation which shows how the basestation updates its clock to synchronize to other basestations.

Figure 7 shows an example of a location server which may be used with certain embodiments of the present invention.

Figure 8 shows the framing structure of GSM cellular signals.

DETAILED DESCRIPTION

Various methods and apparatuses for determining time at a cellular basestation and for otherwise synchronizing cellular basestations in a cellular network are described herein. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. For example, various architectures for basestations and mobile communication stations are provided for illustrative purposes rather than to be construed as limitations of the present invention. It will be evident, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form to facilitate explanation.

In one approach described herein, mobile communication stations are utilized that contain (or are coupled to) GPS receivers which determine both time-of-day and position. **Figure 2** shows an example of such a mobile communication station. This GPS processing may be done in an autonomous mode, if the received signal is large, or with the aid of equipment in the infrastructure (servers) if the received signal-to-noise ratio is low. Note that server equipment (e.g. a location server shown in **Figure 7** and described further below) may also contribute to time-of-day and position determination in situations where improved performance is required (e.g. see U.S. Patents No. 5,945,944; No. 5,841,396; and No. 5,812,087).

In a network such as GSM, the time-of-day information from the GPS receiver may be used to time-tag the framing structure of the received communication (e.g. GSM) signal. For example, the start of a particular GSM frame boundary,

which occurs every 4.6 milliseconds, may be used (see **Figure 8**). There are 2048 such frames per superframe, which lasts 3.48 hours. Hence, if this timing information is passed via normal cellular signaling to the basestation (BS) (e.g. a cellular basestation shown in **Figure 3**), the only major error left in transferring time is the propagation time from the mobile station (MS) (e.g. the mobile cellular communication station of **Figure 2**) to the BS. Of course, some other residual errors may remain, such as multipath delays and transit delays through the MS hardware, and methods for accounting for these residual errors are described below.

A variety of methods may be used to estimate the aforementioned MS-to-BS propagation delay. A first and highly accurate approach can be employed when the MS and/or server have accurately determined the MS position via the GPS unit, and the BS location is precisely known (e.g. predetermined knowledge via survey). In this case, the propagation time may be determined (typically at some network entity) by dividing BS-MS range by the speed of light. Then the BS may determine the timing of its transmitted frame marker by simply subtracting the computed propagation time from the frame marker timing provided by the MS. This method is described further below in conjunction with **Figures 5A, 5B, 6A** and **6B**.

A second and less precise approach to estimating the MS-to-BS propagation delay is made possible by "timing advance" information already available within the MS and BS. The originally intended purpose of such information concerns intra-cell traffic coordination. However, timing-advance metrics can be manipulated in a straightforward manner to yield these MS-to-BS delay estimates. The accuracy afforded by such time alignment parameters is primarily determined by the time

resolution of the communication bit intervals involved. Thus it is possible to achieve propagation delay estimates accurate to within a few or several tens of microseconds. Although less precise than the first delay estimation approach above, this second approach is particularly advantageous in situations where privacy concerns preclude network manipulation of the exact MS position.

As indicated previously, in some applications the basestations need not be synchronized to microsecond type accuracy but only to millisecond or even second type. For these scenarios, it may not be productive to compensate for the MS-to-BS delays since these small delays, on the order or tens of microseconds, are insignificant relative to the required timing accuracy. Thus, coarse time-of-day gotten at the MS may simply be used "as is" to time tag a signal from the BS. This is sent to the BS without the need for precision BS-MS ranging data. This situation is advantageous since GPS receivers are able to perform coarse time tagging at much lower signal levels than is possible for precision time tagging (e.g. see U.S. Patent No. 5,812,087, incorporated herein by reference, and co-pending U.S. Patent Application Serial No. 09/062,232, filed April 16, 1998, incorporated herein by reference). Furthermore, once coarse time-tagging is performed, its accuracy may be maintained over long periods of time due to the high stability of the frequency of the basestation transmitted data.

Figure 4 shows one exemplary method according to an embodiment of the present invention. In operation 151 the mobile cellular system determines a representation of its time-of-day at the mobile cellular communication station. In one embodiment where a GPS receiver, such as GPS receiver 52, is used within a mobile

cellular communication station, such as indicated by 50 shown in **Figure 2**, GPS time may be obtained at the MS by reading GPS time off the GPS signals from the GPS satellites. Alternatively, a technique for determining time as described in U.S. Patent 5,812,087 may be utilized. In this approach, a sample of the GPS signals received at the mobile may be transmitted to a location server or to some other server where this record is processed to determine the time of receipt as described in U.S. Patent 5,812,087. Further, the time-of-day in operation 151 may alternatively be computed using one of the various methods described in co-pending Application Serial No. 09/062,232 which was filed April 16, 1998. The method shown in **Figure 4** continues in operation 153 in which the propagation delay between the mobile cellular communication station and a cellular basestation, such as the cellular basestation shown in **Figure 3**, is determined. It will be appreciated that in certain of the embodiments described above, this operation is optional where the time determined in operation 151 has more error associated with it than the propagation delay. Also as noted above, this propagation delay may be determined by determining the position of the mobile (by means of processing the GPS signals) and determining the position of the cellular basestation. The distance between these two positions divided by the speed of light will determine the propagation delay in operation 153.

In operation 155, the time at the cellular basestation is determined from the time-of-day at the mobile (which was transmitted from the mobile cellular communication system) and from the propagation delay determined in operation 153 if this optional operation is utilized.

Each cellular basestation in a network may employ this procedure in order to synchronize all the basestations relative to one time standard, such as GPS time. In this manner, improved triangulation, or ranging, based upon the use of timing information sent between each of several basestations and a mobile system, may be obtained. Many other uses of timing information may be made. These include allowing more efficient "handoff" of a mobile's communications from one basestation to the next basestation, and permitting unambiguous time to be transmitted throughout the network for various purposes.

Figures 5A, 5B, 6A and 6B will now be described as a further example of an embodiment according to the present invention. This method may be performed with a mobile cellular communication system such as system 50 shown in **Figure 2** and a cellular basestation 101 shown in **Figure 3**.

The mobile cellular communication station 50 shown in **Figure 2** includes a GPS receiver 52 having a GPS antenna 51 and a cellular communication transceiver 54 which includes an antenna 53. Alternatively, GPS receiver 52 may be contained within another chassis (and not integrated within the chassis which holds the components of the mobile station 50 such as the cellular communication transceiver 54) but is coupled to the cellular communication transceiver 54 and is in proximity to the transceiver 54; in this situation, the station 50 does not include a GPS receiver nor does it require one as long as the GPS receiver is coupled to and is co-located with the station 50. The GPS receiver 52 may be a conventional, hardware correlator based GPS receiver, or it may be a matched filter based GPS receiver, or it may be a GPS receiver which uses a buffer to store digitized GPS signals which are processed with

fast convolutions, or it may be a GPS receiver as described in U.S. Patent 6,002,363 in which components of the GPS receiver are shared with components of the cellular communication transceiver (e.g. see **Figure 7B** of U.S. Patent 6,002,363 which is hereby incorporated herein by reference). The cellular communication transceiver 54 may be a modern cellular telephone which operates with any one of the well-known cellular standards including the GSM cellular standard, or the PDC communication standard, or the PHS communication standard, or the AMPS analog communication standard, or the North American IS-136 communication standard, or an unsynchronized wide band spread spectrum CDMA standard. The GPS receiver 52 is coupled to the cellular communication transceiver 54 to provide GPS time and position in one embodiment to the cellular communication transceiver 54 (which then transmits this information to a basestation). Further, the cellular communication transceiver 54 may provide assistance data such as Doppler information or time information to the GPS receiver as described in U.S. Patents 5,841,396 or 5,945,944. The coupling between the GPS receiver 52 and the cellular communication transceiver 54 may also be utilized to transmit a record to or from a cellular basestation for the purpose of matching that record with another record in order to determine the time at the GPS receiver as described in U.S. Patent 5,812,087. In those situations or embodiments where a location server is used to provide assistance data to the mobile cellular communication station for the purpose of determining the position or time at the system 50, or a location server shares in the processing of information (e.g. the location server determines time or the final position calculation of the mobile system 50), it will be appreciated that a location server such as that shown in **Figure 7** and

described further below is connected to a cellular basestation through a communication link to assist in the processing of data. The position of the mobile station is normally not fixed and is normally not predetermined.

Figure 3 shows an example of a cellular basestation which may be used with various embodiments of the present invention. The basestation 101 includes a cellular transceiver 102 which has at least one antenna 102a for communicating signals to and from the mobile cellular communication station which are present in the area served by the cellular basestation 101. For example, a mobile cellular communication station 50 may be one of the mobile stations served by the cellular basestation 101 depending upon the range of the signals typically transmitted by the mobile system 50. The cellular transceiver 102 may be a conventional transceiver used to transmit and receive cellular signals, such as a GSM cellular signal or a CDMA cellular signal. Clock 103 may be a conventional system clock which maintains time-of-day at the cellular basestation. The accuracy of this clock may be improved according to methods of the present invention so as to synchronize this clock with other clocks in other cellular basestations according to the methods described herein. In many cases this clock may be highly stable, but over a period of time the clock will drift by a large amount relative to any initial time setting. Cellular basestation 101 typically also includes a network interface which transfers data to and from the cellular transceiver 102 in order to couple the cellular transceiver to a mobile switching center, as is well known in the art. The cellular basestation 101 may also include a digital processing system 105 which may be either positioned remotely relative to the cellular basestation or may be at the same site as the cellular basestation itself. The digital processing system 105 is

coupled to the clock 103 in order to adjust or recalibrate the time of the clock to thereby synchronize the clock to other clocks in other cellular basestations according to methods of the present invention. In many cases the clock is highly stable but freerunning and it would affect network operation to actually alter the time strokes of the clock. Instead the time associated with the clock epochs can be adjusted. This is what is meant by "recalibrating." The digital processing system 105 is also coupled to the network interface 104 in order to receive data or communications from the mobile switching center and to receive data from the cellular transceiver 102, such as time tagged frame markers transmitted from the mobile systems for the purpose of synchronizing the clock 103 to other clocks in other cellular basestations.

The method shown in **Figures 5A and 5B** begins in operation 201 when a cellular basestation transmits a cellular signal to a mobile cellular communication station. Optionally, this signal may include a request for synchronization information from the mobile system in order to allow the cellular basestation to synchronize itself to other cellular basestations. The cellular basestation provides time tags or markers in its signal which is being transmitted to the mobile system. This marker may be a marker that is an inherent part of the framing structure of the signal. This is further shown in **Figure 6A** in which basestation 1 transmits a signal with a framing structure which includes markers M1, M2, M3, M4, M5, M6, M7, M8 and M9 as shown in the signal 301 of **Figure 6A**. The mobile system in operation 203 of **Figure 5A** receives the cellular signal with the markers. Contemporaneously with the receipt of this cellular signal, the mobile station also receives a GPS signal from a GPS satellite which includes GPS time, as is well known in the art. The mobile

station may then time tag the marker in the cellular signal received from the basestation with GPS time, which represents, in GPS time, a time when the marker was received at the mobile system. This is further shown in **Figure 6A** by the signal 303 which represents the signal received by the mobile 1 from base 1 as delayed by the propagation delay 307. As shown in **Figure 6A**, a time tag 305 has been applied to the marker M1 and this represents the GPS time associated with the time of receipt of this marker at the mobile system. The mobile station in operation 205 determines its position contemporaneously with the time tagging of the marker in the cellular signal. The GPS receiver in the mobile station may determine its position either autonomously (e.g. a conventional hardware correlator based GPS receiver may by itself determine its position by reading ephemeris data from GPS satellites) or it may determine its position with the assistance of a server, such as the location server shown in **Figure 7** which is coupled to the cellular network. In operation 207, the mobile station transmits to the cellular basestation its position (or pseudoranges to allow a location server to determine its position) and the GPS time associated with the marker, which was time tagged by the mobile station.

In operation 209, the cellular basestation computes its time-of-day by using the position of the mobile and its known predetermined position to determine the propagation delay between the mobile and the basestation. This propagation delay is subtracted from the GPS time associated with the marker to determine GPS time at its transmitted marker. This is shown in **Figure 6B** in which the basestation 1 receives the time tag TR1 from the mobile system. This time tag TR1 represents a GPS time which is associated with the marker M1. The propagation delay 307 is subtracted

from the GPS time TR1 to derive the time T1 which is associated with the marker M1. That is, the time T1 is a time tag 309 associated with the marker M1 at the basestation. The current time at the basestation may then be updated by associating the GPS time in the tag 309 with the current frame M9 to produce current time 311 as shown in Figure 6B. That is, there is a known time relationship given the framing structure of the signal 301 between the marker M9 and the marker M1 in the signal 301. The difference in time between these two markers given the known framing structure is added to the time T1 to produce the current time 311. Thus, current time at the cellular basestation is updated from the GPS time which was associated with a transmitted marker which has been time tagged by the mobile. This is shown as operation 211 in Figure 5B. Then in operation 213, the last time that the clock at the cellular basestation was synchronized is optionally saved in order to determine when it is appropriate to update the clock in order to synchronize the clock with other clocks in other cellular basestations. In operation 215, the cellular basestation or a remote entity which assists the cellular basestation may determine when to synchronize again. For example, a set time of several minutes may automatically trigger another synchronization process. Alternatively, other techniques may be utilized to determine when to again synchronize the clock at the basestation to other clocks of other cellular basestations.

Figure 7 shows an example of a location server 350 which may be used with various embodiments of the present invention. For example, as described in U.S. Patent No. 5,841,396, the server may provide assistance data such as Doppler or other satellite assistance data to the GPS receiver in the mobile station 50 or the

location server may perform the final position calculation rather than the mobile station 50 (after receiving pseudoranges or other data from which pseudoranges can be determined from the mobile) and then may forward this position determination to the basestation so that the basestation may calculate the propagation delay. The location server typically includes a data processing unit such as a computer system 351, a modem or other interface 352, a modem or other interface 353, a modem or other interface 354, a mass storage device 355 (e.g. for storing software and data), and optionally a GPS receiver 356. This location server 350 may be coupled to three different networks shown as networks 360, 362, and 364. The network 360 may include the cellular switching center or multiple cellular switching centers and/or the land based phone system switches; alternatively, the modem 353 may be coupled directly to cell sites such as the cellular basestation 101. It will be appreciated that multiple cellular basestations are typically arranged to cover a geographical area with radio coverage and these different basestations are coupled to at least one mobile switching center as is well known in the prior art (e.g. see **Figure 1**). Thus multiple instances of basestation 101 would be geographically distributed but coupled together by a mobile switching center. The network 362 may be a network of reference GPS receivers which provide differential GPS information and may also provide GPS ephemeris data for use in calculating the position of mobile systems. This network is coupled through the modem or other communication interface 354 to the data processing unit 351. The network 364 includes other computers or network components such as the data processing system 105 shown in **Figure 3** (through an optional interconnection not shown in **Figure 3**). Also, the network 364 may

include computer systems operated by emergency operators, such as the Public Safety Answering Points which respond to 911 telephone calls. Various examples of methods for using the location server 350 have been described in numerous U.S. patents and patent applications including U.S. Patents 5,841,396; 5,874,914; 5,812,087; and U.S. Patent Application Serial No. 09/062,232, filed April 16, 1998, all of which are hereby incorporated herein by reference.

The foregoing methods determine the effective time of transmission at the face of the BS antennas. The use of a large number of MS's may tend to reduce errors via averaging procedures. This assumes that system biases may be eliminated.

Concerns about sufficient MS activity to support the timing (e.g. early morning hours) could be ameliorated by placing MS's at various locations and making calls periodically.

Typical timing errors due to the GPS processing at a single MS might be on the order of 10-30 nanoseconds. Thus, other sources of error, such as multipath may dominate.

The stability of the BS oscillator will affect how often timing measurements need to be made and disseminated. It is possible to model the drift vs. time of the BS oscillator and reduce such updates.

Several methods for calibrating for mobile station receiver errors and effects will now be described. In certain embodiments of the invention, the mobile (e.g. mobile cellular communication station 50 of **Figure 2**) determines its location $P_{mobile}=[x_m,y_m,z_m]$ and a time associated with this location T_{mobile}. It may associate this time with a framing marker of a received cellular communication signal by simply

measuring the time delay from the time of location determination (e.g. in GPS time) to that of the framing marker. Alternatively, the location determination may be made at a time equal to that of this framing marker. Thus, without loss of generality we assume that T_{mobile} equals the time of the framing marker as viewed by the mobile.

Suppose the mobile also knows the location of the basestation $P_{base}=[x_b, y_b, z_b]$: Then, if multipath delay is insignificant, the range from the basestation to mobile at time T_{mobile} is

$$R_{Tm}=[(x_m-x_{b)}^2+(y_m-y_{b)}^2+(z_m-z_{b)}^2]^{1/2}.$$

Now, if there were no delays within the receiving circuits the range between the propagation time delay between the basestation and mobile would be R_{Tm}/c, where c is the speed of light.

In order to be more explicit we refer to the time of transmission of a framing marker at the basestation as the time of occurrence of this marker at the face of the transmitting antenna of the basestation. Accordingly, with no multipath delay, or receiver delays, the time of transmission of the frame marker at the basestation's antenna face would be $T_{base}=T_{mobile}-R_{Tm}/c$.

Now, the GPS receiver may have a delay associated with its RF and digital signal processing, which we call b_{GPS}. Similarly there may be a delay associated with the communication receiver's RF and digital signal processing, which we call b_{comm}. Thus, referring to **Figure 2**, b_{GPS} is caused by delays within GPS receiver 52, and b_{comm} is caused by delays within cellular communication transceiver 54. Furthermore, there may be an extra delay in propagation from the basestation to the communication receiver due to multipath, which we call b_{mult}. We assume that this dominates any

multipath delay associated with the GPS measurement. Accordingly, instead of providing an unbiased measurement of the transmission time at the basestation, we provide a measurement with a bias (measured time minus true time) of $b_{mult}+b_{comm}-b_{GPS}$. Typically b_{mult} may dominate the other sources of error, especially if a receiver calibration function is performed (discussed below). Thus, normally, the estimated time of transmission of the framing marker will be late.

One may measure $b_{comm}-b_{GPS}$ by simply using a basestation simulator which transmits the cellular signal with its framing structure and which is directly connected to the antenna port of the mobile and measuring the time of reception of the frame marker at the mobile. In this procedure one uses the mobile's GPS receiver to time tag (with GPS time received by the mobile's GPS receiver) the frame marker. Here it is assumed that the basestation simulator uses a GPS receiver to synchronize its transmissions to the GPS time provided by this GPS receiver. Since the transmission delay from the basestation to receiver is zero, this approach will determine $b_{comm}-b_{GPS}$ without error (except for a small amount of measurement noise). This calibration procedure may be completely automated and is easily incorporated into a receiver testing procedure during manufacture. Some simple modifications to this procedure are possible, such as transmitting simulated signals to the mobile from a simulator in very close proximity to the mobile.

The excess multipath delay, b_{mult}, remains the dominant source of error in synchronizing the basestation. For line-of-sight paths this delay has bias with mean zero. For reflected paths or paths combining direct and reflecting paths, the mean is greater than zero (measured versus true direct path delay). Within a short period of

time, the basestation will, in general, receive a number of estimates for the time associated with each frame marker from several mobile units and perhaps from each mobile unit as well. Call these time-of-day estimates D_1, D_2, ... D_K. The smallest of these estimates will normally have a significantly lower mean bias than any individual measurement, or an average of the measurements. If the number of measurements K are large, one might rank the measurements from low to high and perhaps take an average of the smallest 10% of the measurements, or some similar statistic. This would greatly reduce the mean bias, yet take advantage of some averaging.

If the basestation has a highly stable clock, then one may use this clock to maintain time between updates from the remote mobile units. The clock may be used in the smoothing process to eliminate poor measurements from the mobiles due to multipath. Furthermore, the measurements from the mobile may be used to measure the long term stability of the basestation clock, due to aging, for example. As an example, a GSM hyperframe is around 3.48 hours and a superframe is 6.12 seconds. Accordingly, a hyperframe is around 12528 seconds. A typical GPS time measurement, without differential corrections should be accurate to around 100 nanoseconds. This accuracy allows a measurement of long term frequency of the basestation oscillator equal to around 100 nanoseconds/12528 seconds=8×10^{-12}. Even the measurement over a period of 6.12 seconds allows an accuracy of long-term frequency of around 1.6×10^{-8}. This measurement of long term stability is best done by making several time-of-day measurements with the same mobile receiver. Hence, a stationary or slowly moving mobile is best suited for this purpose. Successive

measurements of the mobiles position will provide the required information regarding the mobile receiver's dynamics.

If there is significant user motion, then it is important that any Doppler related effects do not influence the timing measurements described above. In particular, if the mobile measures time at one instance and is predicting the time-of-day associated with a cellular signal frame boundary occurring at a different instance, an error can result due to the mobile's motion. This is especially the case if the mobile is rapidly moving and/or the difference in these time instances is large. There are a number of ways to deal with this type of problem. For example, if the mobile can determine its velocity, then this data may be supplied to the basestation which can then compensate for errors due to the Doppler associated with the range rate between the mobile and the basestation.

Although the methods and apparatus of the present invention have been described with reference to GPS satellites, it will be appreciated that the teachings are equally applicable to positioning systems which utilize pseudolites or a combination of satellites and pseudolites. Pseudolites are ground based transmitters which broadcast a PN code (similar to a GPS signal) which may be modulated on an L-band carrier signal, generally synchronized with GPS time. Each transmitter may be assigned a unique PN code so as to permit identification by a remote receiver. Pseudolites are useful in situations where GPS signals from an orbiting satellite might be unavailable, such as tunnels, mines, buildings or other enclosed areas. The term "satellite", as used herein, is intended to include pseudolite or equivalents of pseudolites, and the

term GPS signals, as used herein, is intended to include GPS-like signals from pseudolites or equivalents of pseudolites.

In the preceding discussion the invention has been described with reference to application upon the United States Global Positioning Satellite (GPS) system. It should be evident, however, that these methods are equally applicable to similar satellite positioning systems, and, in particular, the Russian Glonass system. The Glonass system primarily differs from GPS system in that the emissions from different satellites are differentiated from one another by utilizing slightly different carrier frequencies, rather than utilizing different pseudorandom codes. The term "GPS" used herein includes such alternative satellite positioning systems, including the Russian Glonass system.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

CLAIMS

What is claimed is:

1. A method for performing time synchronization between at least two basestations comprising a first basestation and a second basestation of a cellular communication system, the method comprising:

determining a time-of-day and a location of a first mobile cellular station;

transmitting through a first cellular communication link the time-of-day and the location of said first mobile cellular station to said first basestation;

determining a time-of-day of said first basestation from said time-of-day and said location of said first mobile cellular station together with a known location of said first basestation;

determining a time-of-day and a location of a second mobile cellular station;

transmitting through a second cellular communication link the time-of-day and the location of said second mobile cellular station to said second basestation;

determining a time-of-day of said second basestation from said time-of-day and said location of said second mobile cellular station together with a known location of said second basestation;

wherein said first mobile cellular station and said second mobile cellular station each utilize a co-located satellite positioning system receiver to determine said times of day and said locations of said first and second mobile cellular stations.

2. A method as in claim 1 wherein said time-of-day of said first mobile cellular station is measured with respect to a frame synchronization epoch present within a cellular communication signal that is transmitted from said first basestation and received by said first mobile cellular station.

3. A method as in claim 1 wherein said determining of said time-of-day of said first basestation is with respect to a frame synchronization epoch present within a cellular communication signal that is transmitted from said first basestation.

4. A method as in claim 1 wherein said cellular communication link utilizes one of a GSM communication standard, a PDC communication standard, a PHS communications standard, an AMPS analog communication standard, a North American IS-136 communication standard, or an unsynchronized wide band spread spectrum CDMA standard.

5. A method as in claim 1 wherein said first mobile cellular station and said second mobile cellular station are the same station.

6. A method as in claim 1 wherein said first mobile cellular station and said second mobile cellular station are different, separate mobile cellular stations.

7. A system for performing time synchronization between at least two basestations comprising a first basestation and a second basestation of a cellular communication system, said system comprising:

a first satellite position system (SPS) receiver capable of determining a time-of-day and a location of a first mobile cellular station, which is co-located with said first SPS receiver and wherein said first mobile cellular station is capable of transferring said time-of-day and said location of said first mobile cellular receiver to said first basestation;

a first measurement apparatus coupled to said first basestation, said first measurement apparatus being capable of determining a time-of-day of said first basestation from said time-of-day and location of said first mobile cellular station together with a known location of said first basestation;

a second satellite position system (SPS) receiver capable of determining a time-of-day and a location of a second mobile cellular station, which is co-located with said second SPS receiver and wherein said second mobile cellular station is capable of transferring said time-of-day and said location of said second mobile cellular station to said second basestation;

a second measurement apparatus coupled to said second basestation, said second measurement apparatus being capable of determining a time-of-day of said second basestation from said time-of-day and said location

of said second mobile cellular station together with a known location of said second basestation.

8. A system as in claim 7 wherein said first SPS receiver is integrated within an enclosure with said first mobile cellular station.

9. A system as in claim 8 wherein said first SPS receiver and said first mobile cellular station share at least one common component.

10. A system as in claim 7 wherein said time-of-day of said first mobile cellular station is measured with respect to a frame synchronization epoch present within a cellular communication signal that is transmitted from said first basestation to said first mobile cellular station.

11. A system as in claim 7 wherein said determining of said time-of-day of said first basestation is with respect to a frame synchronization epoch present within a cellular communication signal that is transmitted from said first basestation.

12. A system as in claim 7 wherein said cellular communication link utilizes one of a GSM communication standard, a PDC communication standard, a North American IS-136 communication standard, a PHS communications standard, an AMPS analog communication standard, or an unsynchronized wide band spread spectrum CDMA standard.

13. A system as in claim 7 wherein said first mobile cellular station and said second mobile cellular station are the same station and wherein said first SPS receiver and said second SPS receiver is the same receiver.

14. A system as in claim 7 wherein said first mobile cellular station and said second mobile cellular station are different, separate stations and wherein said first SPS receiver and said second SPS receiver are different, separate receivers.

15. A method as in claim 1, further comprising a further method for determining a mobile cellular station time bias in a mobile cellular station, which incorporates a co-located SPS receiver, wherein said further method comprises:

placing said mobile cellular station in proximity to a cellular basestation simulator;

synchronizing said cellular basestation simulator to a precision time reference;

determining a time-of-day of said mobile cellular station using said co-located SPS receiver;

using said time-of-day to determine said mobile cellular station time bias;

storing said mobile cellular station time bias in a memory attached to said mobile cellular station.

16. A method as in claim 15 wherein said mobile cellular station includes substantially the same circuitry as said first mobile cellular station and its SPS receiver

and includes substantially the same circuitry as said second mobile cellular station and its SPS receiver.

17. A method for establishing time at a first basestation in a cellular communication system, said method performed in a mobile cellular communication station, said method comprising:

determining a position information of said mobile cellular communication station, wherein a location of said mobile cellular communication station is determined from said position information;

determining a time indicator which represents a time-of-day at said mobile cellular communication station, wherein said time indicator is determined relative to a signal which is available at said first basestation;

transmitting at least one of said position information and said location, and transmitting said time indicator from said mobile cellular communication station, said time indicator and at least one of said position information and said location being used to establish a time at said first basestation such that said first basestation is synchronized to other basestations in said cellular communication system.

18. A method as in claim 17 wherein said mobile cellular communication station comprises a satellite positioning system (SPS) receiver which determines said position information which at least comprises a pseudorange to a SPS satellite and wherein

said signal which is available at said first basestation is a cellular communication signal which is transmitted from said first basestation to said mobile cellular communication station, and wherein said time indicator is associated with a marker in said signal.

19. A method as in claim 18 wherein said time indicator comprises at least one of a sampling of an SPS signal received by said SPS receiver and a time-of-day message in said SPS signal.

20. A method as in claim 19 wherein a location server receives said position information and determines said location and provides said position to said first basestation.

21. A method for establishing time at a first basestation in a cellular communication system, said method being performed remotely relative to a mobile cellular communication station, said method comprising:

receiving a time indicator, which represents a time-of-day at said mobile cellular communication station, from said mobile cellular communication station, wherein said time indicator is determined relative to a signal which is available to said first basestation;

determining a time at said first basestation from said time indicator such that said first basestation is synchronized to other basestations.

22. A method as in claim 21 wherein said signal is a cellular communication signal which is transmitted from said first basestation to said mobile cellular communication station.

23. A method as in claim 22 further comprising:

receiving a location of said mobile cellular communication station, wherein said time at said first basestation is also determined from said location of said mobile cellular communication station and from a known, predetermined location of said first basestation.

24. A method as in claim 23 wherein said location is not predetermined as said mobile cellular communication station is not fixed and said location and said known predetermined location determine a propagation delay between said mobile cellular communication station and said first basestation.

25. A method as in claim 24 wherein said other basestations synchronize to said first basestation by receiving other time indicators from at least one of said mobile cellular communication station and other mobile cellular communication stations and wherein said other time indicators and said time indicator are based upon a same time standard.

26. A method as in claim 25 wherein said same time standard is a Global Positioning System time.

27. A basestation apparatus for use in a cellular communication system, said basestation apparatus comprising:

a wireless cellular transceiver;

a network interface coupled to said wireless cellular transceiver; and

a clock coupled to said wireless cellular transceiver, said wireless cellular transceiver receiving a time indicator from a remote mobile cellular communication station which represents a time-of-day at said mobile cellular communication station, wherein said time indicator is determined relative to a signal which is available to said basestation apparatus and wherein a time for said clock is determined from said time indicator such that said basestation apparatus is synchronized to other basestations.

28. A basestation apparatus as in claim 27 wherein said signal is a cellular communication signal which is transmitted from said basestation apparatus to said mobile cellular communication station.

29. A basestation apparatus as in claim 28 wherein said network interface transfers land based communications to said mobile cellular communication station through said wireless cellular transceiver and wherein said wireless cellular transceiver receives a location of said mobile cellular communication station, wherein said time for said

clock is also determined from said location and from a known, predetermined location of said first basestation.

30. A basestation apparatus as in claim 29 further comprising:

a digital processing system coupled to said clock and coupled to at least one of said wireless cellular transceiver and said network interface, said digital processing system determining a propagation delay from said location and said known, predetermined location, and using said propagation delay and said time indicator to set said time on or provide a correction to said clock.

31. A basestation apparatus as in claim 28 wherein said other basestations synchronize to said basestation apparatus by receiving other time indicators from at least one of said mobile cellular communication station and other mobile cellular communication stations and wherein said other time indicators and said time indicator are based upon a same time standard.

32. A mobile cellular communication station comprising:

a wireless cellular transceiver;

a satellite positioning system (SPS) receiver coupled to said wireless cellular transceiver, said SPS receiver determining a time indicator which represents a time-of-day at said mobile cellular communication station and which is determined relative to a signal which is available to a

basestation, and wherein said wireless cellular transceiver transmits said time indicator to said basestation and wherein said time indicator is used to establish a time at said basestation such that said basestation is synchronized to other basestations which are capable of wireless communication with said mobile cellular communication station.

33. A mobile cellular communication station as in claim 32 wherein said SPS receiver determines a location and said wireless cellular transceiver transmits said location to said basestation and wherein said signal is a cellular communication signal which is transmitted from said basestation to said mobile cellular communication station and wherein said time indicator is associated with a marker in said signal.

34. A mobile cellular communication station as in claim 33 wherein said time indicator is a time-of-day message in an SPS signal which is received by said SPS receiver.

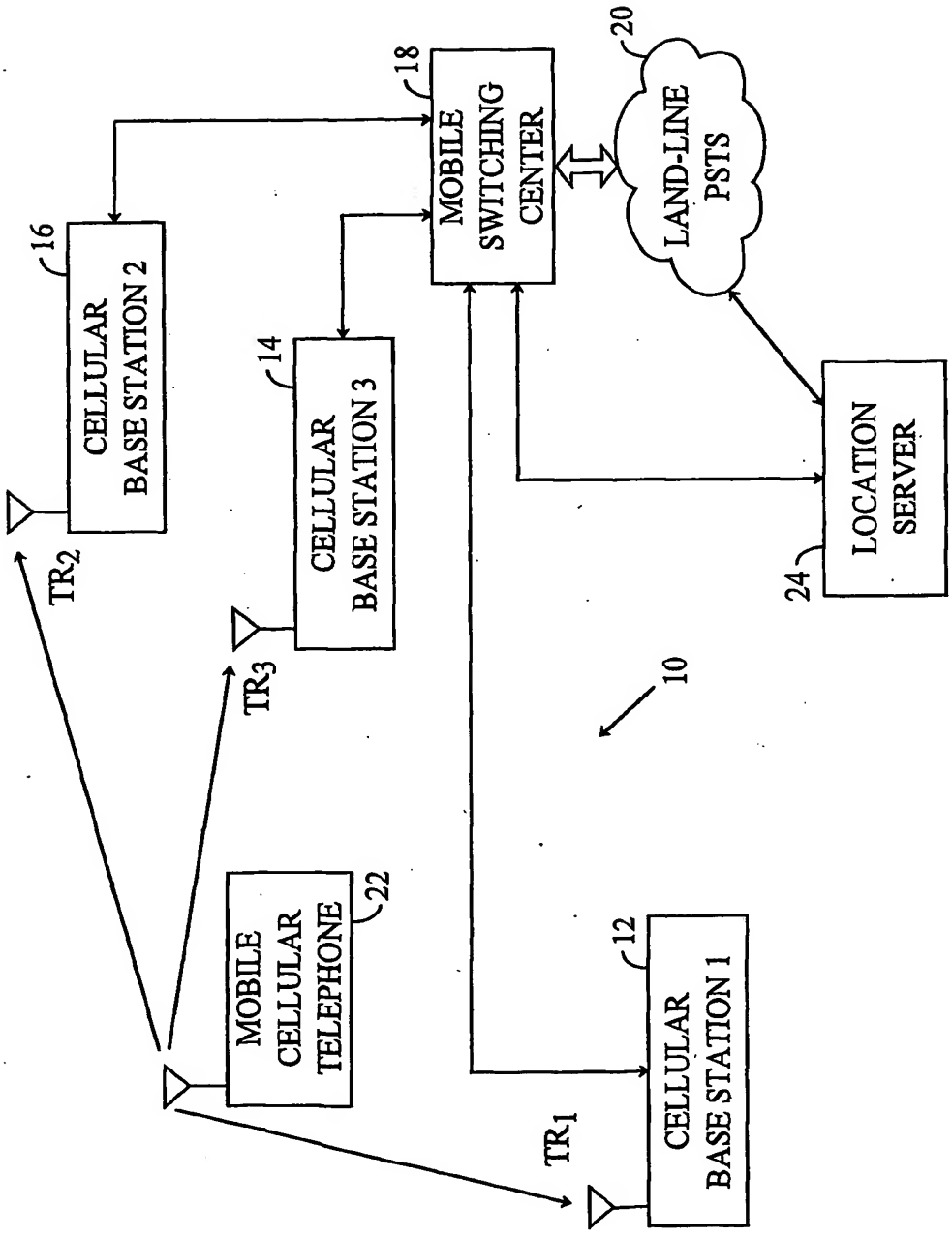

FIG. 1
(PRIOR ART)

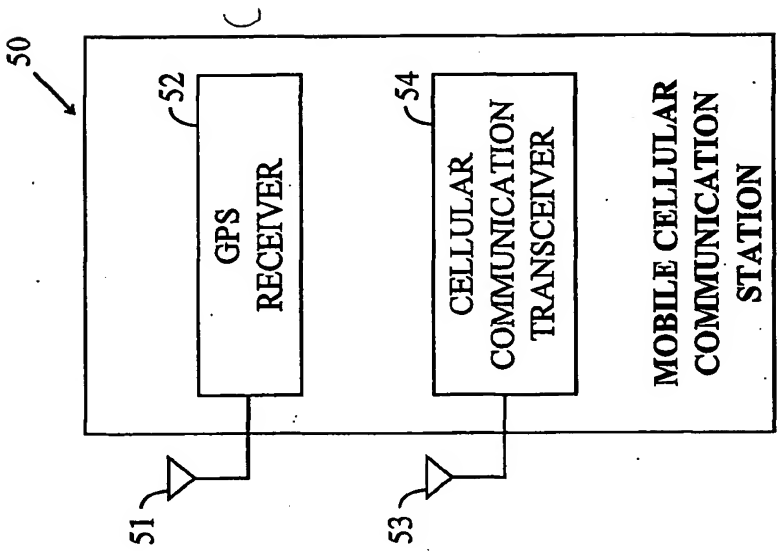
50
52
GPS RECEIVER
54
CELLULAR COMMUNICATION TRANSCEIVER
MOBILE CELLULAR COMMUNICATION STATION
51
53

FIG. 2

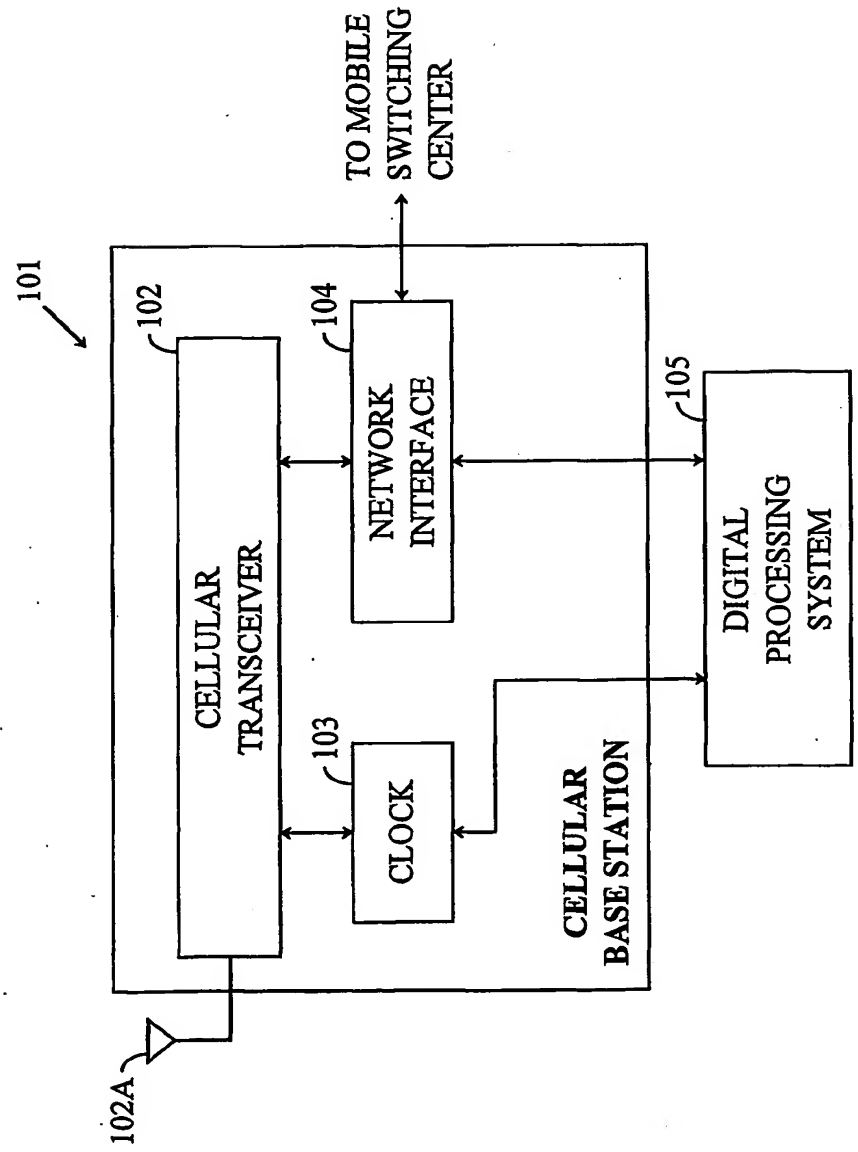
TO MOBILE SWITCHING CENTER
101
102
104
105
CELLULAR TRANSCEIVER
NETWORK INTERFACE
DIGITAL PROCESSING SYSTEM
103
CLOCK
CELLULAR BASE STATION
102A

FIG. 3

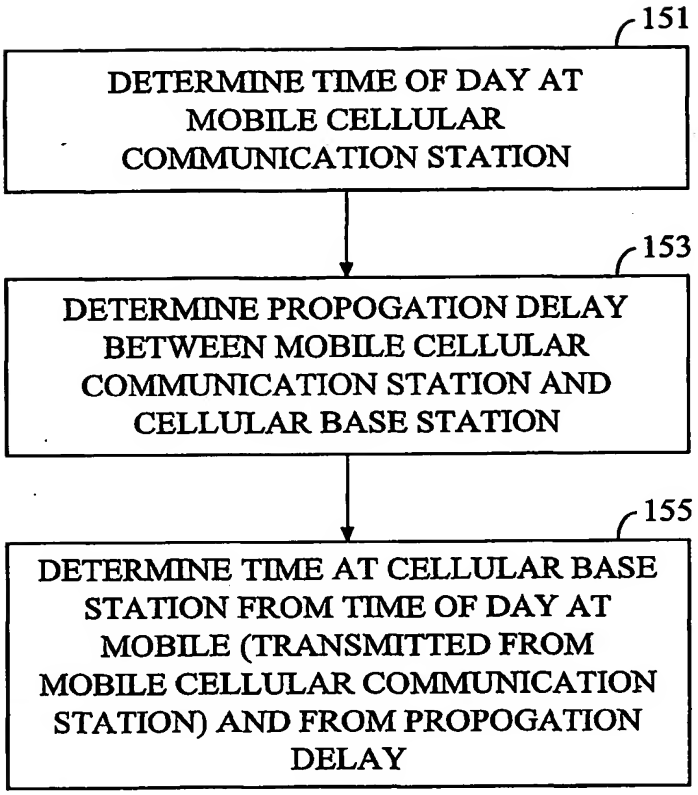
151
DETERMINE TIME OF DAY AT MOBILE CELLULAR COMMUNICATION STATION
153
DETERMINE PROPOGATION DELAY BETWEEN MOBILE CELLULAR COMMUNICATION STATION AND CELLULAR BASE STATION
155
DETERMINE TIME AT CELLULAR BASE STATION FROM TIME OF DAY AT MOBILE (TRANSMITTED FROM MOBILE CELLULAR COMMUNICATION STATION) AND FROM PROPOGATION DELAY

FIG. 4

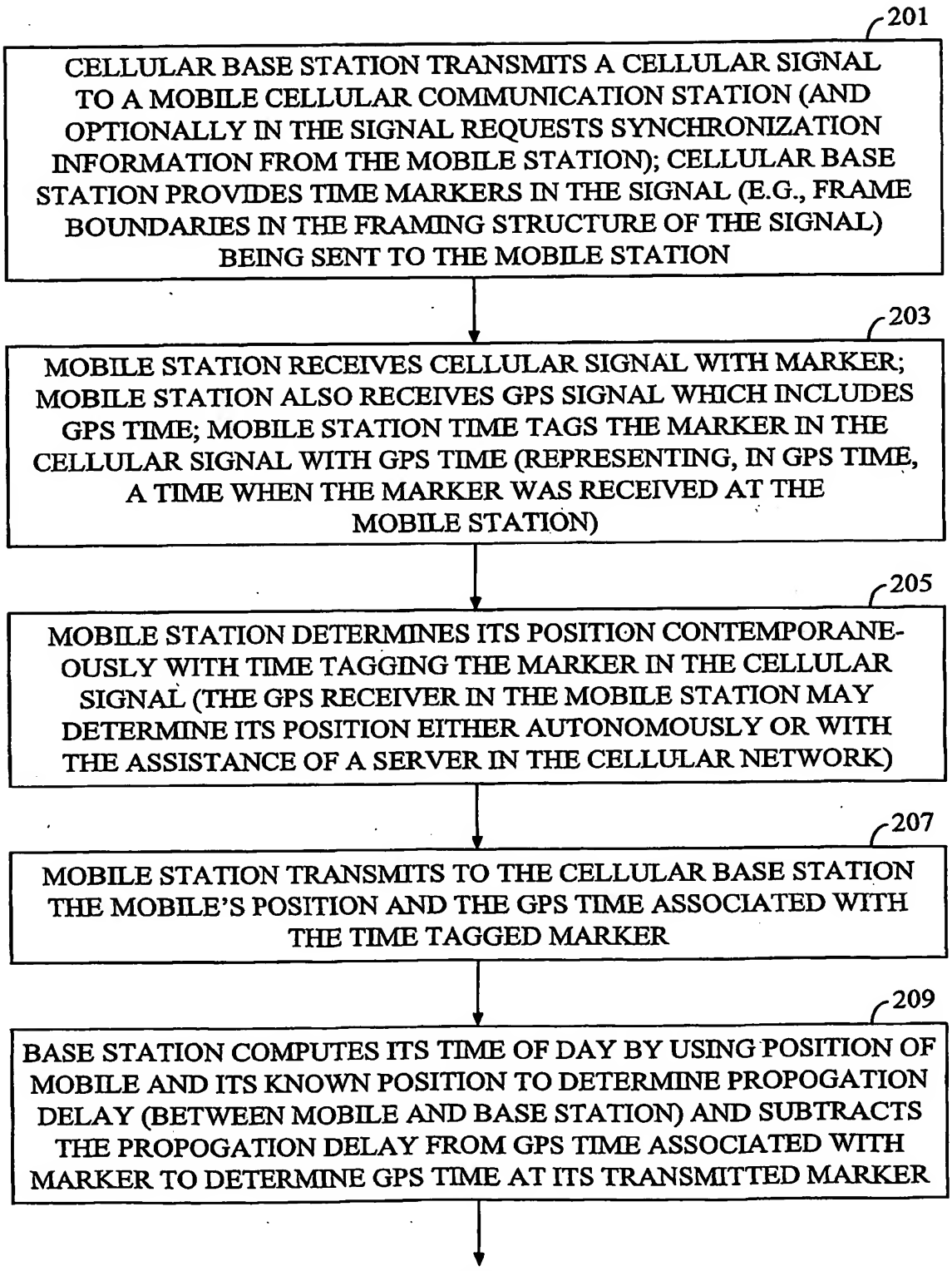
201
CELLULAR BASE STATION TRANSMITS A CELLULAR SIGNAL TO A MOBILE CELLULAR COMMUNICATION STATION (AND OPTIONALLY IN THE SIGNAL REQUESTS SYNCHRONIZATION INFORMATION FROM THE MOBILE STATION); CELLULAR BASE STATION PROVIDES TIME MARKERS IN THE SIGNAL (E.G., FRAME BOUNDARIES IN THE FRAMING STRUCTURE OF THE SIGNAL) BEING SENT TO THE MOBILE STATION
203
MOBILE STATION RECEIVES CELLULAR SIGNAL WITH MARKER; MOBILE STATION ALSO RECEIVES GPS SIGNAL WHICH INCLUDES GPS TIME; MOBILE STATION TIME TAGS THE MARKER IN THE CELLULAR SIGNAL WITH GPS TIME (REPRESENTING, IN GPS TIME, A TIME WHEN THE MARKER WAS RECEIVED AT THE MOBILE STATION)
205
MOBILE STATION DETERMINES ITS POSITION CONTEMPORANEOUSLY WITH TIME TAGGING THE MARKER IN THE CELLULAR SIGNAL (THE GPS RECEIVER IN THE MOBILE STATION MAY DETERMINE ITS POSITION EITHER AUTONOMOUSLY OR WITH THE ASSISTANCE OF A SERVER IN THE CELLULAR NETWORK)
207
MOBILE STATION TRANSMITS TO THE CELLULAR BASE STATION THE MOBILE'S POSITION AND THE GPS TIME ASSOCIATED WITH THE TIME TAGGED MARKER
209
BASE STATION COMPUTES ITS TIME OF DAY BY USING POSITION OF MOBILE AND ITS KNOWN POSITION TO DETERMINE PROPOGATION DELAY (BETWEEN MOBILE AND BASE STATION) AND SUBTRACTS THE PROPOGATION DELAY FROM GPS TIME ASSOCIATED WITH MARKER TO DETERMINE GPS TIME AT ITS TRANSMITTED MARKER
TO FIG. 5B

FIG. 5A

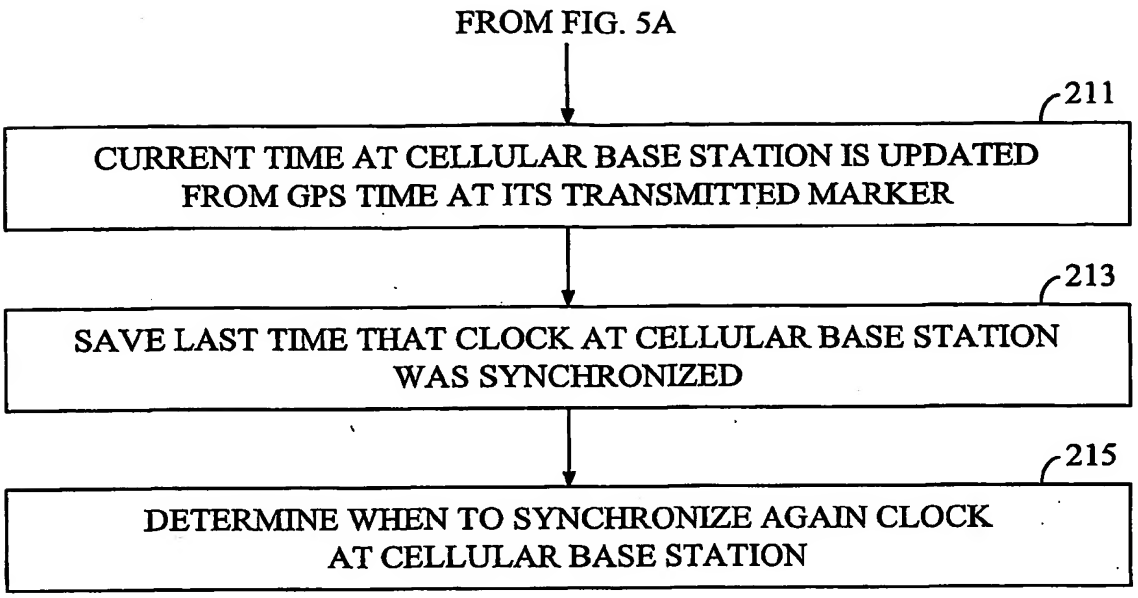
FROM FIG. 5A
211
CURRENT TIME AT CELLULAR BASE STATION IS UPDATED FROM GPS TIME AT ITS TRANSMITTED MARKER
213
SAVE LAST TIME THAT CLOCK AT CELLULAR BASE STATION WAS SYNCHRONIZED
215
DETERMINE WHEN TO SYNCHRONIZE AGAIN CLOCK AT CELLULAR BASE STATION

FIG. 5B

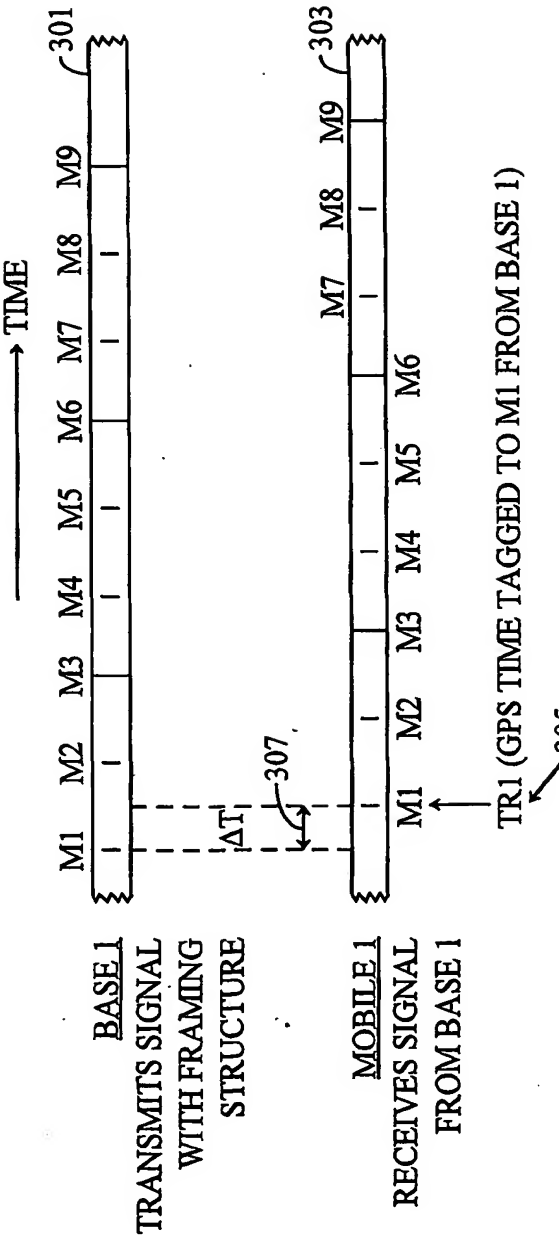
TIME
M1 M2 M3 M4 M5 M6 M7 M8 M9
301
BASE 1
TRANSMITS SIGNAL
WITH FRAMING
STRUCTURE
ΔT
307
M1 M2 M3 M4 M5 M6 M7 M8 M9
303
MOBILE 1
RECEIVES SIGNAL
FROM BASE 1
TR1 (GPS TIME TAGGED TO M1 FROM BASE 1)
305

FIG. 6A

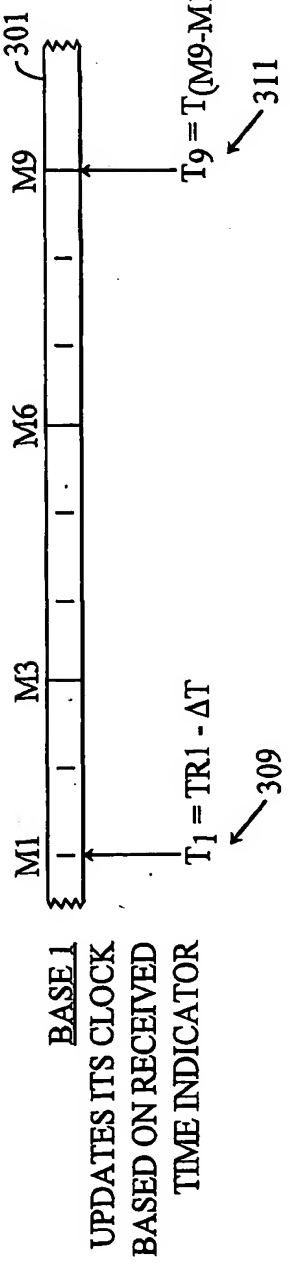
M1 M3 M6 M9
301
BASE 1
UPDATES ITS CLOCK
BASED ON RECEIVED
TIME INDICATOR
T1 = TR1 - ΔT
309
T9 = T(M9-M1) + T1
311

FIG. 6B

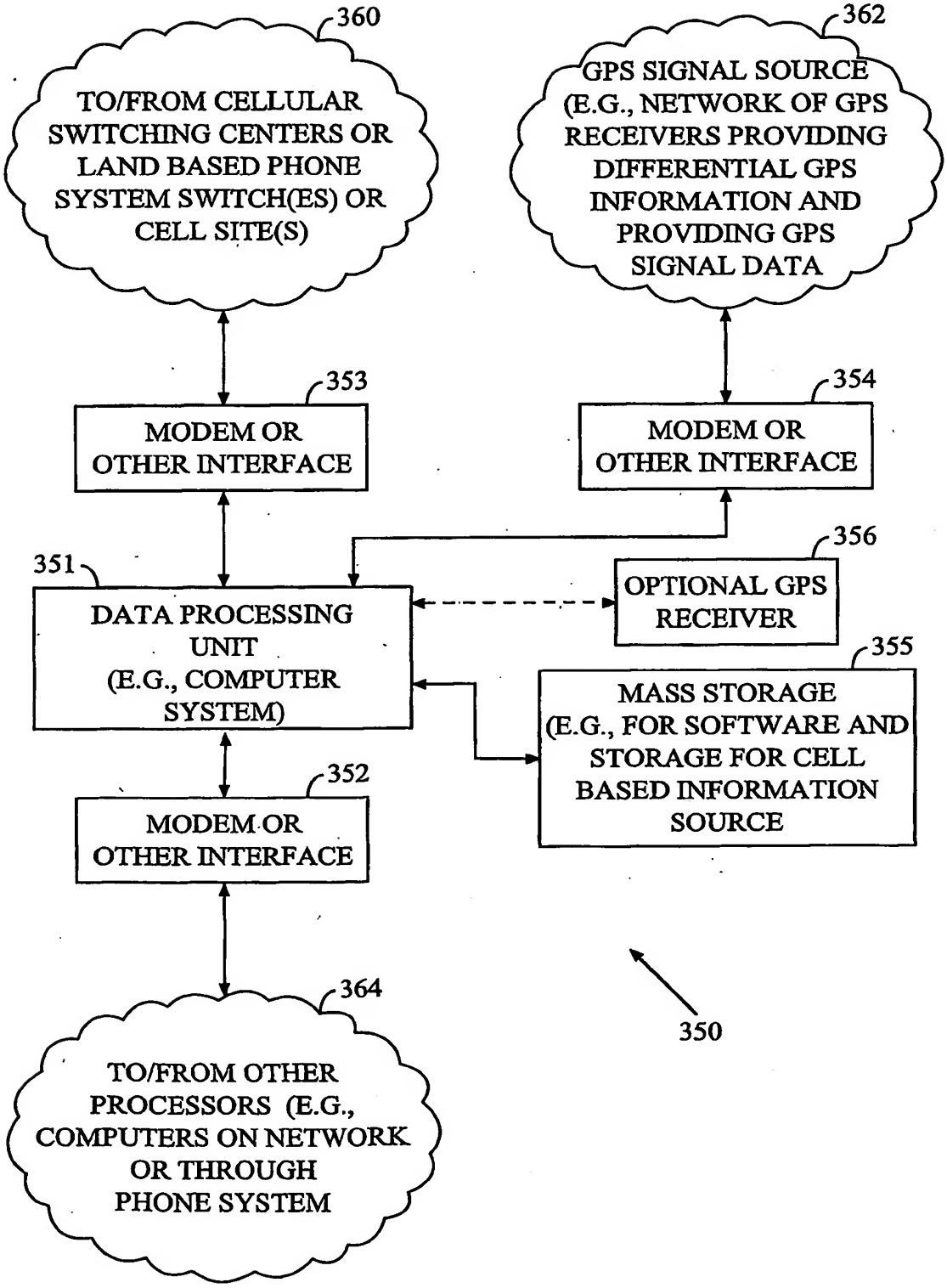
360
TO/FROM CELLULAR SWITCHING CENTERS OR LAND BASED PHONE SYSTEM SWITCH(ES) OR CELL SITE(S)
362
GPS SIGNAL SOURCE (E.G., NETWORK OF GPS RECEIVERS PROVIDING DIFFERENTIAL GPS INFORMATION AND PROVIDING GPS SIGNAL DATA
353
MODEM OR OTHER INTERFACE
354
MODEM OR OTHER INTERFACE
356
OPTIONAL GPS RECEIVER
351
DATA PROCESSING UNIT (E.G., COMPUTER SYSTEM)
355
MASS STORAGE (E.G., FOR SOFTWARE AND STORAGE FOR CELL BASED INFORMATION SOURCE
352
MODEM OR OTHER INTERFACE
364
TO/FROM OTHER PROCESSORS (E.G., COMPUTERS ON NETWORK OR THROUGH PHONE SYSTEM
350

FIG. 7

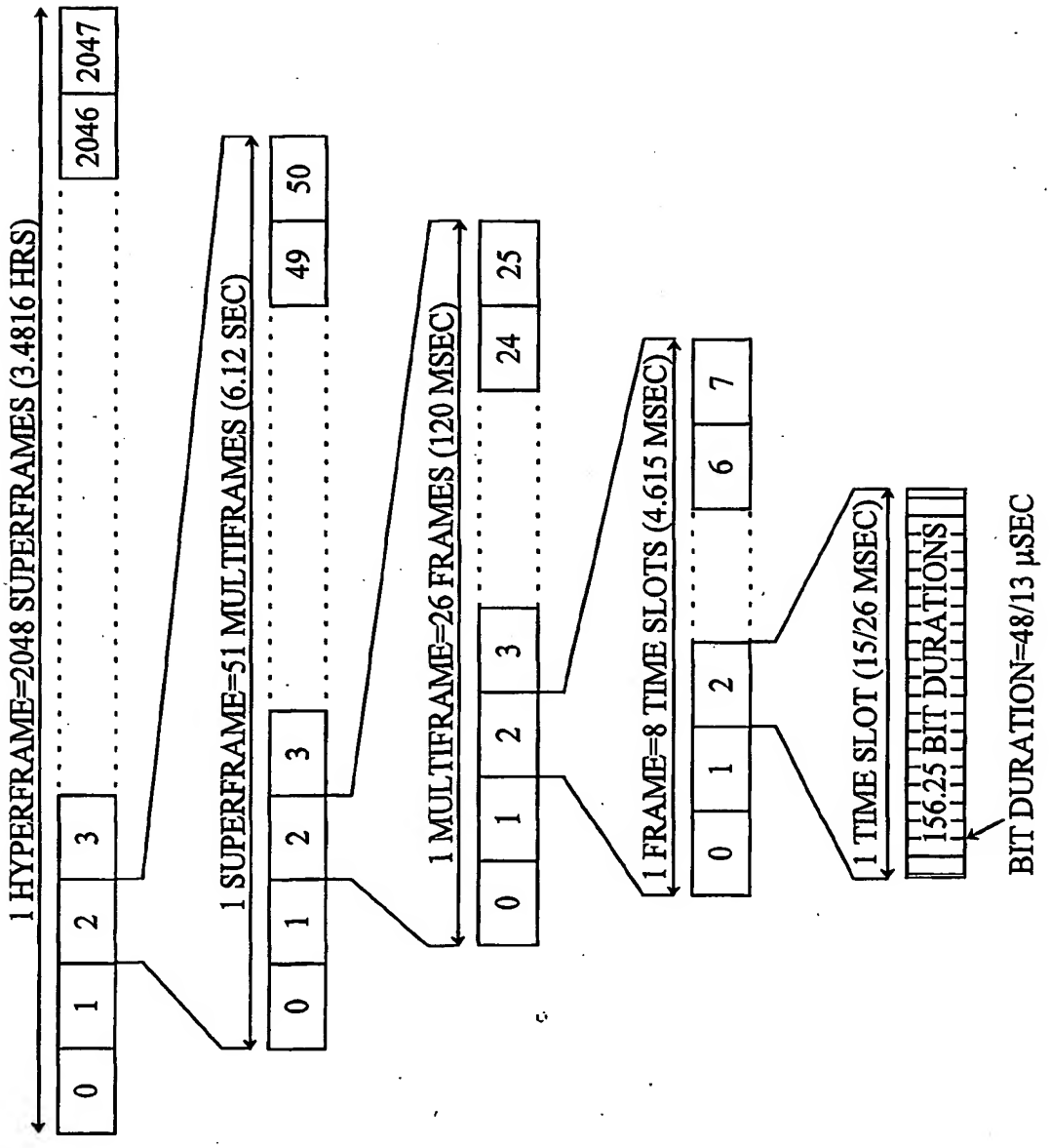
1 HYPERFRAME=2048 SUPERFRAMES (3.4816 HRS)
0
1
2
3
2046
2047
1 SUPERFRAME=51 MULTIFRAMES (6.12 SEC)
0
1
2
3
49
50
1 MULTIFRAME=26 FRAMES (120 MSEC)
0
1
2
3
24
25
1 FRAME=8 TIME SLOTS (4.615 MSEC)
0
1
2
6
7
1 TIME SLOT (15/26 MSEC)
156.25 BIT DURATIONS
BIT DURATION=48/13 µSEC

FIG. 8

INTERNATIONAL SEARCH REPORT

Int ional Application No
PCT/US 01/17113

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	WO 01 55803 A (ERICSSON TELEFON AB L M) 2 August 2001 (2001-08-02) page 2, line 23 -page 3, line 12 page 3, line 22 - line 25 page 7, line 3 - line 20 page 8, line 3 - line 17 page 11, line 15 -page 13, line 7 ---	1-14, 17-34
E	WO 01 76285 A (CELLGUIDE LTD ;COHEN HANOCH (IL); FRIEDMAN MARK M (IL); NIR JOSEPH) 11 October 2001 (2001-10-11) page 5, line 24 -page 7, line 26; figures 1,2,5,6 --- -/--	1-14, 17-34

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 November 2001	20/11/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax (+31–70) 340–3016	Sorrentino, A

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Int :ional Application No
PCT/US 01/17113

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 09, 30 July 1999 (1999-07-30) & JP 11 112410 A (ADVANTEST CORP), 23 April 1999 (1999-04-23) abstract	1,7,17, 21,27,32
A	US 6 016 322 A (GOLDMAN HERBERT B) 18 January 2000 (2000-01-18) column 3, line 40 - line 46 column 4, line 36 - line 52 column 5, line 6 - line 30	1,7,17, 21,27,32
A	WO 01 20818 A (QUALCOMM INC) 22 March 2001 (2001-03-22) page 9, line 12 - line 23 page 12, line 32 - line 12 page 13, line 26 -page 14, line 6	1,7,17, 21,27,32

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

nformation on patent family members

Int ional Application No
PCT/US 01/17113

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0155803 A	02-08-2001	WO 0155803 A2	02-08-2001
WO 0176285 A	11-10-2001	WO 0176285 A1	11-10-2001
JP 11112410 A	23-04-1999	NONE	
US 6016322 A	18-01-2000	NONE	
WO 0120818 A	22-03-2001	AU 7586500 A WO 0120818 A1	17-04-2001 22-03-2001